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RENOVATION OF WORN-OUT SOILS.

BY

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UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., January 3, 1906.

SIR: I have the honor to transmit herewith a paper on the Renovation of Worn-out Soils and respectfully recommend that it be published as a Farmers' Bulletin. This paper was prepared by Mr. W. J. Spillman, of this Bureau, who has given special attention to the methods that have been successfully used in restoring fertility to exhausted soils in various sections of this country.

Acknowledgments are due Dr. J. A. Bonsteel, of the Bureau of Soils, for reading this manuscript and for valuable suggestions in the treatment of the subject. In addition, the paragraphs relating to substances thrown off in the soil by growing plants were written by him, as was also a portion of what is said regarding the manner in which mineral plant food becomes available in the soil.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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RENOVATION OF WORN-OUT SOILS.

PRELIMINARY REMARKS.

For nearly two centuries after the advent of the white man in America farming was confined to a narrow strip of land adjacent to the Atlantic; the population was sparse, and when a field became worn out the near-by woodland was cleared. As population increased, the younger generation crossed the Alleghenies, beginning the tide of migration which has moved westward until the present time, but which has now occupied nearly all of the easily available lands from the Alleghenies to the Pacific. In its westward course this advancing host farmed virgin soils for a century. The marvelous development which has occurred in this country during the past century was made possible by the abundant fertility of the new lands brought under cultivation and the consequent abundance and cheapness of farm products.

So long as plenty of fertile land remained unoccupied in the West the exhaustion of the older land in the East was a matter of concern only to the farmers of the older settled communities. But now we are confronted by the necessity of tilling soils whose ability to produce satisfactory crops has been greatly impaired. There is even a perceptible flow of immigration from the high-priced lands of the Middle West to the depleted lands of the Atlantic seaboard. This has been made possible by the recent remarkable development of agricultural science, which has demonstrated the feasibility of restoring fertility to exhausted soils. Agricultural science is also responsible for the present movement from the city to the country. The conditions of country life have been alleviated; the farm has been made attractive by adding the zest of intellectual occupation in the splendid agricultural literature of the day; and farming, when intelligently followed, has been made profitable, even on lands that were formerly unproductive.

DIFFERENCES IN NATURAL FERTILITY.

There is a vast difference in the natural fertility of soils. Some do not produce well from the start unless special attention is given to making them productive; others produce large crops for a short time and then rapidly diminish in fertility; while others, known as strong

soils, remain productive for many years without attention to their fertility. But even the strongest soils will wear out in time unless they are intelligently managed. Curiously enough, as the tide of migration went westward in this country, the settlers found soils of increasing natural fertility as they went, and in each new settlement the opinion prevailed that the soil was inexhaustible. But even the strong soils of the western prairies have now been cropped with grain and abused by improper methods of tillage until they show signs of approaching exhaustion.

Fortunately, while the rich soils of the West were being depleted of their fertility, the development of agricultural science was going forward with rapid strides, and, while there is much yet to learn about the soil, we now know, in a general way, the steps necessary to build up and maintain soil fertility. In fact, soils that were originally only moderately productive, and that have been rendered almost sterile by improper methods of farming, can be made richer than they ever were.

NATURE OF THE SOIL.

In order to understand the methods necessary for restoring worn-out soils, let us consider what occurs in a fertile soil that is growing a large crop. Imagine a cubic inch of ordinary field soil magnified into a cubic mile. It would then present very much the appearance of a mass of rocks varying from the size of a pea to masses several feet in diameter. Scattered among these rock masses would be many pieces of decaying plant roots and other organic matter, resembling rotting logs in a mass of stones and gravel. The masses of organic matter would be found to contain large quantities of water, and to somewhat resemble wet sponges, while every mass of rock would have a layer of water covering its surface. The open spaces between the solid masses would be filled with air.

If a crop were growing on this soil, its roots would be found threading their way among the masses of rock and decaying roots, and pushing these aside by the pressure exerted by the growing root. From the surface of the growing root, near its tip, small hollow threads (the root hairs) extend into the open spaces and suck up the water covering the rock particles. The root hairs are not open at the end; they absorb the water through their walls. The plant food is dissolved in this water, but is usually present in exceedingly small quantities. While the plant is growing a constant stream of water flows up through it and evaporates at its leaves. For every pound of growth in dry matter made by the plant, from 300 to 800 pounds of water flow up through it.

The plant food substances dissolved in the soil water may be divided into two classes according to their ultimate source.

MINERAL PLANT FOOD.

Plants in their growth make use of thirteen chemical elements, nine of which they secure directly from the soil. These are called the mineral plant foods; they are phosphorus, potassium, calcium, magnesium, sodium, iron, silicon, chlorin, and sulphur. We have already seen that the soil consists mainly of small particles of rock. The rock particles are of many kinds, but nearly all kinds contain more or less potassium, calcium, phosphoric acid, etc. Every year the soil water dissolves off a thin surface layer from each particle. Plants appropriate this water and thus secure mineral plant food.

Many generations of plants have thus been collecting their small toll of food from the soil and storing it up in their tissues. The amount of plant food made ready for plant use during each growing season through the slow solution of the mineral particles of the soil is doubtless supplemented to a considerable degree by the same kinds of material set free from the organic matter also found in the soil—that is, the mineral matter originally secured from the dissolved minerals, but built into plants during some former season, may again be used by other plants when the old matter is given an opportunity to decay in the soil. These foods derived directly from the mineral matter of the soil and indirectly from it through the growth, death, decay, and return of former crops are also supplemented in many cases by the application of mineral matter in the form of commercial fertilizers.

NITROGEN COMPOUNDS.

In addition to the nine elements already mentioned, the growing plant requires four other elements, as follows: Hydrogen, which it secures from water (water is a compound of hydrogen and oxygen); oxygen, which it secures partly from water and partly from the air; carbon, which is secured from carbonic-acid gas in the air; and nitrogen.

Nitrogen is in many respects the most important of all the plant-food elements. It is not found in appreciable quantities in the rock particles of the soil. Ordinary plants depend for their nitrogen entirely on decaying organic matter. As decay proceeds nitrates are formed from the nitrogen contained in organic matter. The nitrates are exceedingly soluble, and unless soon made use of by growing crops they are washed out of the soil. Nitrogen is therefore usually the first element to become exhausted in the soil.

Fortunately, there are certain species of bacteria that can use atmospheric nitrogen, of which there is an inexhaustible supply. One family of plants—the legumes—has learned to exchange work with these bacteria, and these plants are thus easily supplied with an abundance

of nitrogen in a form they can use. When these nitrogen-fixing bacteria are present in a soil on which a leguminous crop is growing, the bacteria invade the roots of the legume and live there. Their presence is usually made manifest by swellings—the so-called tubercles—on the roots of thrifty plants of clover, alfalfa, beans, peas, and other legumes. Nitrogen from the soil air filters into the roots, where the bacteria appropriate it, manufacture an abundance of nitrates, and give a portion to the plant in exchange for starch. The tissues of leguminous plants become very rich in nitrogenous compounds, and when they decay in the soil they set free large amounts of nitrates for the use of any crop which may be growing at the time.

The cultivation of leguminous crops is one of the most important and economical means of maintaining a supply of nitrogenous plant food in the soil. Nitrates may, of course, be supplied in commercial fertilizers; but fertilizers containing nitrogen are very expensive, and it usually pays better to supply nitrogen by growing legumes or by the application of stable manure, which is rich in nitrogen when properly handled. In good farm practice both stable manure and leguminous crops are used as sources of nitrogen.

SOIL MOISTURE AND HUMUS.

In order to produce a ton of dry hay on an acre of land it is necessary that the growing grass pump up from that acre approximately 500 tons of water. In order to supply this enormous quantity of water, the soil must not only be in condition to absorb and hold water well, but it must be porous enough to permit water to flow freely from soil grain to soil grain. The presence of large quantities of decaying organic matter (humus) adds enormously to the water-holding capacity of the soil. One ton of humus will absorb 2 tons of water and give it up readily to growing crops. Not only that, but the shrinkage of the particles of decaying organic matter and the consequent loosening of soil grains keep the soil open and porous.

Furthermore, humus of good quality is exceedingly rich in both nitrogen and mineral plant food. The maintenance of fertility may almost be said to consist in keeping the soil well supplied with humus. The first step in renovating worn-out soils is to give them an abundant supply of humus of good quality. Perhaps the best source of humus is stable manure containing both the liquid and the solid excrement, especially when the stock are fed rich nitrogenous foods. Even a poor quality of barnyard manure, which has had much of the plant food leached out of it, has considerable value because of the humus it makes.

Another cheap and valuable source of humus, but one which must be used understandingly, is crops grown to turn under as manure.

The legumes are especially valuable for this purpose because of the nitrogen they contain, but other crops, such as rye, and even corn sown thick, may sometimes be made to supply large quantities of humus of fair quality. Crops thus used are called green manures. They are more fully discussed farther on (p. 12).

SOIL AIR.

A proper circulation of air in the soil is just as important as any other factor of plant growth. Nearly half of the volume of ordinary soils is occupied by air spaces. The air spaces in the soil wind in and out between the soil particles, just as they do in a pile of larger stones. If the layer of water on the surface of the soil grains becomes so thick as to stop the air passages here and there the soil is then too wet for most crops and needs drainage. Plants have no special breathing organs, the oxygen required in their breathing finding entrance all over the surface of the plant. Plant roots must therefore be supplied with air, and hence the soil must be porous enough to permit of free circulation of air. A good supply of humus and proper tillage will accomplish this result in clay soils. Sandy soils are usually too porous, needing humus to help them retain water.

Another reason why air must circulate freely in the soil is that large quantities of oxygen are required to insure proper decay of organic matter to supply plant food. Also, carbonic-acid gas is produced by the decay of organic matter, and this must escape easily to make room for the atmospheric oxygen needed in the soil. The movement of air in the soil is frequently shown by the bubbles which appear at the surface of the soil just after a hard rain. As the water soaks into the soil it drives the air out, and bubbles may be seen at the surface if water enough is present to form them.

One of the most important objects of plowing is to loosen up the soil and mix fresh air with it.

SUBSTANCES THROWN OFF IN THE SOIL BY GROWING PLANTS.

Considerable evidence has been accumulated during recent years to show that the cause of the failure of some soils to produce satisfactory crops may be ascribed to unfavorable conditions produced in the soils by the plants themselves. It is thought that during the growth of the plant certain unknown organic substances are given off which, when they accumulate in the soil to any extent, are harmful to the further growth of plants of the kind that produced them. It is possible that some of the benefits known to arise from systematic crop rotation may be explained on this basis. These harmful substances seem to be disposed of rapidly by certain soils, usually those in which organic matter

is readily converted into humus. Other soils, usually marked by a lack of the brown carbonized organic matter, do not seem to possess this property of removing harmful plant products to such a degree. This idea is in accord with the common experience that dark-colored soils, well filled with organic matter, are usually very productive.

In connection with the study of these poisonous organic products, it has been found that they may be destroyed or at least rendered harmless in a variety of ways. Barnyard manure or decaying organic matter, such as a green crop of rye or cowpeas, turned under has a very marked effect in freeing the soil from them. Almost all of the common commercial fertilizing materials act more or less in the same way. Commercial fertilizers for soil improvement have, therefore, another value besides adding plant food. Thorough and complete airing of the soil will often destroy or overcome these poisonous substances. The beneficial effects of plowing and of thorough surface tillage are thus explained, in part at least, on the basis of the thorough aeration secured. When the same crop is not grown oftener than every three or four years on the same land the injurious substances a crop throws off seem to have time to disappear before the same crop is grown again; hence the benefit from crop rotation. When the soil is well supplied with humus there is seldom any trouble from this source, and the same crop may be grown year after year with good yields, though continuous cultivation of the same crop may invite injury from certain insects and fungous diseases which live over in the soil or in the remains of the crop.

EFFECTS OF TILLAGE.

Improper methods of tillage add very greatly to the evil effects that result from lack of humus. In many parts of the country the land is plowed only 3 or 4 inches deep. Below the plowed stratum the soil becomes sour, densely packed, and unfit for plant roots. When such soils are plowed deep and this sour packed subsoil is mixed with the upper portion, the growth of many crops is greatly retarded. This has led many farmers to believe that deep plowing is ruinous. Some farmers have tried to remedy the difficulty by subsoiling. The subsoil plow breaks up the packed layer but does not throw it out on top. But while subsoiling does break up the hard layer into chunks it does not pulverize it or put humus into it. In most cases work done in subsoiling is practically wasted, and it is doubtful if it ever pays. A much better method is to plow a little deeper each year until a depth of 8 or 10 inches is reached. This gives a deep layer of good soil, particularly if the supply of humus is kept up.

When new soil, or that which has lain undisturbed for several years, is broken up, it is always best to plow deep from the beginning, for

the deeper layers will be about as fertile as any, except the top inch or two. It is wise, too, never to plow the same depth twice in succession. In general, fall plowing should be from 7 to 9 or 10 inches and spring plowing from 5 to 7 inches deep. There are special cases in which these rules do not apply, but their discussion would take us too far from the purpose of this paper.

We plow the soil in order to loosen up its texture and get air into it; also to turn under stubble, manure, etc., to make humus. Killing weeds is another object accomplished by plowing. After a soil has been thoroughly pulverized to great depths, so that there is no danger of turning up packed clay, the deeper the plowing the better the crops. But the cost also increases with depth, so that ordinarily it does not pay to plow more than about 10 inches deep.

Some crops prefer rather a loose seed bed. Millet is such a crop. Farmers sometimes plow a second time in order to sow millet on freshly plowed land. Other crops, such as wheat and alfalfa, prefer a fairly compact seed bed; hence, frequent harrowing and rolling after plowing is good practice before seeding to these crops. Nevertheless, it pays to plow the land for them, even if we have to compact it again before seeding. The plowing aerates the soil and helps to set plant food free.

EFFECT OF PLOWING SOIL WHEN TOO WET OR TOO DRY.

Sandy soils are usually not injured by handling when wet; but the case is different with clay soils. A fair quality of brick can be made from any heavy clay soil by working it thoroughly when wet and then drying it in the sun. The effect produced by working clay soils wet is known as puddling. Irrigation ditches in the West are puddled by first flooding them to make them muddy and then driving bands of sheep along in this mud. This makes the bottom impervious to water and prevents loss from leakage. If a clay soil is plowed, or even harrowed, when too wet, it is more or less puddled. In this condition it becomes cloddy and impervious to air and water. Old roadways that have been thoroughly puddled from traffic in all kinds of weather may be distinguished in fields many years after they have been plowed up and put into cultivation.

The proper time to plow land is when it is just moist enough to break up mellow, neither wet enough to leave a slick surface where rubbed by the moldboard nor dry enough to break up in large clods; or, as the southern farmer puts it, when the soil has a good season in it. If continued rain follows wet plowing, little harm follows; but hot, dry winds would soon leave only a mass of unmanageable clods. In spring and midsummer plowing, particularly, it is of the utmost

importanee to run the harrow immediately after the plow. This prevents the formation of elods. In late fall plowing, the clods are no disadvantage, for they will be broken up by freezing and thawing during the winter.

TERRACING AND SOIL WASHING.

One of the most serious results that follow shallow plowing, at least in hilly regions, is the washing away of the soil in torrential rains. In some seetions, particularly in the southern portion of the Appalaehian Mountain region, farmers have attempted to eounteract this by means of terraees. Much of the farm land in the Carolinas, Georgia, and Alabama is nothing but a series of stair steps. When terraees are properly laid out they do prevent washing, but they are a very expensive means of aecomplishing the end sought. They oeeupy land that ought to be in crops. They seed the land with weeds. When improperly eonstructed, and they usually are, they cause great ditehes to be washed in the hillsides. Besides this they cut the land up into small, irregular patches and greatly inerease the cost of tillage. There is a better way of preventing washing in nearly all eases.

In the first place, where land has been plowed only 3 or 4 inehes deep for several years the subsoil beeomes impervious to water and ean not absorb a heavy rainfall fast enough to prevent its flowing over the surfaee. But when the land is plowed gradually deeper until a good depth of loose soil is obtained, and partieularly when an abundanee of humus is supplied from grass roots and stubble, or from green erops turned under, or, better still, from barnyard manure, the soil becomes so porous that the heaviest rains cause little or no flowing of water on the surfaee. Striking illustrations of this faet are to be found on the farm of Mr. W. L. Williamson, of Jackson County, Ga., and on the farm of Rev. J. D. Detrich, described in the Yearbook of the Department of Agrieulture for 1903 under the title "A Model Farm." In the Yearbook paper referred to, illustrations are shown of two fields lying side by side, both in rye. The pictures were taken within a few feet of eaeh other. In one two large ditehes had just been filled with dirt. In the other there was no tendeney to wash. Mr. Williamson's farm is located in a region where terracing is very general. Since he abandoned cotton eulture and began dairying he has plowed up all his terraees, and his land does not wash. He plows deep and manures heavily. But it is possible to aeeomplish similar results, even on a farm largely devoted to cotton, by deep plowing and the use of green manures to supply humus.

IMPROVING THE SOIL.

We have seen that poverty in soil may be due to poor texture, unfavorable structure, lack of humus, deficiencies in the amount, form, or proportion of plant food, and to the presence of harmful mineral and organic compounds. With the exception of nitrogen, most soils, even those that are very poor, usually contain an abundant supply of plant food, though sometimes other elements are lacking or are present only in those forms that plants can not use.

To increase fertility we must improve texture and add plant food and humus. Tillage may do much to improve texture, but tillage alone will not suffice. We must add humus. In doing so we add plant food, and make the soil more permeable to air and water.

INCREASING THE STOCK OF HUMUS.

There are three general methods of supplying humus to the soil. The first and best is the addition of stable manure. When properly managed it adds large quantities of both plant food and humus. But manure is not always available. When such is the case, the best thing to do is to make it available. Raise more forage, keep more stock, and make more manure. But this takes time and capital, so that other means are sometimes necessary. When stable manure is not to be had, we may plant crops for the purpose of turning them under, thus adding large quantities of humus at comparatively little cost. Plowing under green crops is called green manuring. Under certain conditions this is an excellent practice. Crops adapted to this purpose and the method of using them are discussed farther on (p. 12).

A third method of adding humus is to grow crops like clover and timothy. These crops are usually left down for two years or more. During this time their roots thoroughly penetrate the soil. Old roots decay and new ones grow. When the sod is plowed up, more or less vegetable matter is turned under. This, with the mass of roots in the soil, adds no small amount to the supply of humus. Another advantage from the cultivation of clovers and alfalfa is found in the fact that they are deep-rooted plants, and when their roots decay they leave channels deep into the earth, thus aiding in the absorption of rains and letting in air to sweeten the soil.

STABLE MANURE.

Properly handled, stable manure is by all means the best remedy for poverty of the soil. Very few farmers handle manure so as to get even as much as half the possible value from it. There is probably no greater waste in the world than in connection with the handling of manure by the American farmer. Five-eighths of the plant food in

manure is found in the liquid part of it. This is usually all lost. Not only is this the case, but the solids are piled beside the barn, frequently under the eaves, where rains wash away much of their value. Fermentation in these manure piles also sets free much of the nitrogen to escape into the air.

The writer has seen few farmers who had no apologies to make for their methods of handling manure. He has seen one, however, who believed he was getting every particle of value from the manure it is possible to get. The farm in question was a dairy farm, and the methods used are not applicable to all types of farms. The cows were kept in their stalls the year around. Every day in the year they had either silage or green stuff from the fields. They also had enough dry hay to keep the manure from being too washy, and what grain they needed. Behind each row of eight cows was a ditch 18 inches wide and 8 to 10 inches deep. This ditch was cleaned thoroughly every morning after milking hours. After the cleaning, a small quantity of wood ashes was sprinkled in the ditch to dry it; then a layer about 1½ inches deep of rotten sod or leaf mold was added. Next morning the contents of the ditch were lifted into a cart by means of forks, and the cart went immediately to the field where the manure was scattered. In exceptionally bad weather the ditch was sometimes left for two days. This farmer always had a place to put manure.

This method may not be applicable to all dairy farms, but it is the ideal to be followed as closely as circumstances will permit. If there is no sod on which to haul manure in wet weather, it is well to have a cemented pit under cover, in which to place the manure until it can be hauled to the field. When the ground is frozen in winter, manure can be spread on almost any field. Generally speaking, it should be spread on the field next to be plowed. The above method of handling manure gets both liquids and solids on the land. If any leaching occurs, let it be into the soil where the leachings will do the most good. Recent investigations indicate that when liquid manure is applied to the soil, the plant food in the manure is absorbed and held in the soil, and is not immediately washed out if not made use of by the plants.

GREEN MANURES.

The practice of plowing under green crops as manures is not very general, and we do not know as much as we should like to know of the value of this method. Some crops do not thrive when sown on land into which a green crop has recently been plowed. This is particularly true of those crops that like a solid seed bed, or which are sensitive to acids. When a heavy green crop is plowed under, it goes through a fermentation not unlike that which occurs in a barrel of kraut, resulting in the formation of a considerable amount of acid.

Alfalfa is particularly sensitive to acids, and it also requires a compact seed bed. It is unwise, therefore, to green-manure the land just before seeding to alfalfa. The cereals, particularly wheat and rye, do not do well after a green manure. On the other hand, potatoes and corn are not seriously injured by green manures. In fact potatoes are benefited by them, since the resulting acid condition of the soil prevents the development of potato scab.

Generally speaking, when it is desirable to plow in a green crop before fall-sown crops, it should be done a month or six weeks before planting time, and the soil should be harrowed frequently or otherwise compacted. A few good rains will wash out most of the acids and aid in compacting the soil. The acid may also be counteracted by adding lime.

Crimson Clover.

Along the Atlantic coast as far north as New Jersey and south at least to Georgia, crimson clover, frequently called German clover, thrives as a winter annual. Like all the legumes it stores up much nitrogen and greatly enriches the soil in this element. This crop deserves a much wider field of usefulness than has yet been accorded it. In the northern part of its territory it should be sown in July. In the South, September is supposed to be the best time to sow it. It is best adapted to sowing in corn or cotton. In sections where it has not previously been grown it frequently fails, apparently from lack of its proper bacteria. It is therefore well to inoculate the seed when it is sown the first time.

This crop furnishes valuable winter pasture, makes good hay if cut when just coming into full flower, and is valuable as a green feed in spring. It helps to fill the gap in the soiling system between green wheat and early corn. Perhaps its greatest usefulness is as a green manure. It may be plowed under any time in the spring and be followed by corn or potatoes.

In this connection, the practice of a farmer near Hagerstown, Md., is of interest. Ten years ago he began sowing crimson clover in corn at the last plowing, covering the seed with the cultivator, and using 10 pounds of seed to the acre. In the spring the clover was plowed under and another crop of corn planted. Ten consecutive crops of corn have been taken from this field, a crop of crimson clover being plowed under each spring. The yield of corn has increased during that time from about 35 bushels, in the beginning, to about 50 bushels at the present time. Evidently the practice was a good one in this case.

Those who are not familiar with crimson clover should try it on a small scale at first, as there have been many failures with it. The following five-year rotation is a good one on stock farms in middle lati-

tudes, and shows one way of securing the benefits of crimson clover as a green manure: Corn with crimson clover sown at last cultivation, corn, oats, wheat, clover (common red).

Vetches.

The vetches can be made to occupy a somewhat similar place as a green manure, at least in the South. Prof. E. R. Lloyd, of the Mississippi Agricultural Experiment Station, reports an instance of a cotton grower who uses hairy vetch and cowpeas in a unique manner. At the beginning he sowed hairy vetch broadcast in his cotton at the last plowing. The next spring the old cotton stalks were left standing, the new rows of cotton being planted in the middles, which were bedded up in the usual manner. When the vetch had made seed, the stalk cutter was run over the old rows and they were then plowed out and cowpeas planted in their place. Subsequent cultivation was between the cotton and the cowpea rows. In the autumn the vetch sprang up again and grew during the winter, the cowpeas being left to decay in place. The following spring the cotton rows followed the old cowpea rows, and the vetch was left to seed on the old stalks as before. This method requires that the cotton rows should be about 5 feet apart, but the farmer who practices it assured Professor Lloyd that his yield of cotton had doubled in the three years since the practice was started. This method is worth the attention of farmers who grow cotton continuously on the same land, and this class includes the vast majority of cotton growers.

Rye.

Rye is not half appreciated by the American farmer. It is very hardy, will grow on the poorest land, makes good winter and spring pasture, and if sown early enough makes good fall pasture. It is a good spring soiling crop, giving the earliest bite of green stuff. It makes a fair quality of hay if cut in bloom or before, and its straw always sells at good prices and makes the best of bedding for cattle and horses. It is also an excellent green manure crop for turning under in early spring. While it does not add nitrogen as the clovers do, it makes a great deal of humus, and thus improves the texture of worn-out soils. It will grow in any section that can grow any of the small grains. Where corn or potatoes or cowpeas are grown after corn, rye may be sown in the corn at the time of "laying by," or may be sown on the stubble after the corn is cut, and be plowed under in the spring for any of the crops mentioned.

Cowpeas.

The cowpea has been a boon to the farmers of the South, and its value is coming to be generally recognized. During the past few years the demand for cowpea seed has exceeded the supply, and high prices

have resulted. A good way to secure its beneficial effect on the soil is to sow it in corn at the last cultivation. This practice has become well-nigh universal in the South and is extending northward. This crop may also be sown after wheat, oats, or rye, at least from the latitude of Washington, D. C., southward, and may be harvested for hay in time for another fall crop to be sown. Prof. H. J. Waters, of the Missouri Agricultural Experiment Station, has grown cowpeas between wheat crops for several years past and increased the yield of wheat in a marked degree.

It seldom pays to turn under a crop of cowpeas in the green state. It is better practice to make hay of them, feed the hay, and put the manure back on the land. As is the case with all legumes, the roots of the cowpea crop add a great deal of nitrogen to the soil, and have a marked effect on fertility. If a heavy green crop of cowpeas is plowed under in the autumn it is best not to plant the land until the following spring. A very good plan for bringing up the fertility of a worn-out field is to sow rye in the fall, plow this under in the spring, harrow thoroughly, let the land lie a month, and then sow cowpeas. Cut the peas for hay and sow rye again. A few seasons of such treatment will restore fertility to the soil. Fortunately, both of these crops will grow on very poor land.

Miscellaneous Green-Manure Crops.

Almost any crop may be used as a green manure, as occasion demands. Those previously mentioned are more generally used for this purpose than others. In plowing up clover sod, many farmers, particularly on fields most in need of manure, wait until the clover is nearly ready to cut for hay before plowing, in order to get the additional nitrogen and humus thus produced. Buckwheat is frequently grown as a green manure. This crop is planted in early summer or late spring and turned under in the autumn. Even corn and sorghum have been used for this purpose. They produce large amounts of humus when thickly planted. Sufficient time should be given after plowing in such rank growth to allow the soil to settle and the resulting acids to wash out of the soil before planting another crop. In southern California, fenugreek and Canadian field peas (the so-called "English pea" of the South) are used extensively as winter cover crops in orchards. They are then plowed under in spring as green manure.

TYPES OF FARMING THAT BUILD UP THE SOIL QUICKLY.

The quickest way to build up a worn-out soil when barnyard manure is not plentiful is to give it a course of treatment like that just described; then grow only forage crops, buy grain to feed with them, and return all the manure thus produced to the land. Dairy farming permits

such a system to be practiced. No other type of farming builds up land so rapidly.

Another type that gives fairly quick results is to grow a succession of pasture crops for hogs, keep the hogs on these pastures, and feed them a fourth to a half ration of grain. In middle latitudes the following system is adapted to this type of farming: Grow corn enough for the pigs on part of the farm, sowing either cowpeas or crimsom clover or rye in the corn yearly, to keep up fertility. The two latter crops furnish winter pasture for the pigs. On the remainder of the farm run the following three-year rotation: Sow oats in early spring; follow by rye sown early in August; follow this by sorghum the following spring; in September or October sow rye again after the sorghum; late the next spring sow either sorghum or cowpeas, and begin over again with oats the succeeding spring. This may be made a four-year rotation by inserting artichokes or sweet or Irish potatoes between the August-sown rye and the sorghum. If these crops are all pastured down, the hogs being fed a little grain meanwhile, the soil will improve. With such a system, at least on clay soils, the hogs must not be allowed on the fields when the soil is wet, as they will puddle it to such an extent as to do serious injury. To avoid this difficulty, there should be an additional field of good sod for the hogs to run on in wet weather. In sections where alfalfa thrives, hogs may be pastured on this crop in summer (in winter also in the far South) and fed a little corn. In winter such crops as rape and kale may take the place of the alfalfa, and the grain feed may thus be increased. Such a system takes nothing from the land, but care must be used not to puddle the soil by pasturing in wet weather. There should be a field of good sod in reserve for such periods.

SUMMARY.

We may sum up the matter briefly thus: To build up and maintain fertility in the soil, feed a large part of the crops and return the manure to the land. If manure is not available, plow under crops grown for the purpose. Plow deep (but do not subsoil). Grow leguminous crops for the nitrogen they add to the soil.

Commercial fertilizers and lime may be important means of improving the soil, but the fertilizer requirements of different soils and different crops in different seasons are so little understood that we are not yet in a position to make positive recommendations that are of general application.

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